Evolving narratives on signal functions for monitoring maternal and newborn health services: A meta-narrative inspired review

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ABSTRACT

Emergency obstetric care (EmOC) signal functions are a shortlist of key clinical interventions capable of averting deaths from the five main direct causes of maternal mortality; they have been used since 1997 as a part of an EmOC monitoring framework to track the availability of EmOC services in low- and middle-income settings. Their widespread use and proposed adaptation to include other types of care, such as care for newborns, is testimony to their legacy as part of the measurement architecture within reproductive health. Yet, much has changed in the landscape of maternal and newborn health (MNH) since the initial introduction of EmOC signal functions. As part of a project to revise the EmOC monitoring framework, we carried out a meta-narrative inspired review to reflect on how signal functions have been developed and conceptualised over the past two decades, and how different narratives, which have emerged alongside the evolving MNH landscape, have played a role in the conceptualisation of the signal function measurement. We identified three overarching narrative traditions: 1) clinical 2) health systems and 3) human rights, that dominated the discourse and critique around the use of signal functions. Through an iterative synthesis process including 19 final articles selected for the review, we explored patterns of conciliation and areas of contradiction between the three narrative traditions. We summarised five meta-themes around the use of signal functions: i) framing the boundaries; ii) moving beyond clinical capability; iii) capturing the woods versus the trees; iv) grouping signal functions and v) measurement challenges. We intend for this review to contribute to a better understanding of the discourses around signal functions, and to provide insight for the future roles of this monitoring approach for emergency obstetric and newborn care.

Keywords: Signal functions; maternal health; newborn health; emergency obstetric care (EmOC); emergency obstetric and newborn care (EmONC); abortion; monitoring and evaluation; meta-narrative

Introduction

This review of the evolving narratives on signal functions for maternal and newborn health (MNH) is part of the Re-Visioning Emergency Obstetric and Newborn Care (EmONC) project to review, rethink and revise the emergency obstetric care (EmOC) monitoring framework that has been in use since its initial publication in 1997 in *Guidelines for monitoring the availability and use of obstetric services* (WHO, UNICEF, and UNFPA, 1997). The EmOC monitoring framework has been much more than simply a technical measurement guide; it helped to define EmOC and put it on the policy map (AbouZahr, 2003). It provided a conceptually simple approach for health sector planners and managers, as well as researchers, to "see" their EmOC system, to know whether it was functioning roughly as policy and planning documents supposed, to identify weaknesses, and ultimately to recommend or take, focused action (Abegunde *et al.*, 2015; Banke-Thomas *et al.*, 2016; Bosomprah *et al.*, 2016; Dominico *et al.*, 2022).

At the core of the 1997 *Guidelines* and then the 2009 revised *Guidelines* were signal functions (Figure 1a) – a shortlist of emergency obstetric interventions capable of treating the direct obstetric complications that caused the majority of maternal deaths (WHO, UNICEF, and UNFPA, 1997; WHO *et al.*, 2009) (Figure 1b). The framework arranged signal functions into basic and comprehensive levels, as shown in Figure 1a, with surgical capacity being the key element distinguishing comprehensive from basic. Signal functions are measured by counting whether or not a facility performed the function in a specified timeframe (typically 3 months), posed as a question to a clinician in-charge at the facility. The performance of all six basic signal functions within a set time period defined a facility as a functioning basic EmOC facility, while all eight signal functions were needed for a functioning comprehensive EmOC facility. These then enabled the calculation of EmOC availability. As part of the overall *Monitoring Emergency Obstetric Care (EmOC) Handbook*, EmOC availability was the first indicator in a 6-indicator set that generated information on access, utilisation and quality as well (WHO *et al.*, 2009).

To date, the original eight signal functions published in 1997 and then revised to nine EmOC signal functions in 2009 (Figure 1a) are the only signal functions that have been formally adopted and endorsed by UN agencies (WHO, UNICEF, and UNFPA, 1997; WHO *et al.*, 2009). However, multiple adaptations of the signal function framework have been proposed, suggesting the utility of the approach. There have been attempts to integrate newborn services (Gabrysch S *et al.*, 2012; Moxon S.G. *et al.*, 2019) and routine childbirth services (Gabrysch S et al, 2012) and to use the concept of signal functions in other areas of reproductive health, including antenatal and postnatal care (McCauley, Kirsty Lowe, *et al.*, 2022; McCauley, K Lowe, *et al.*, 2022), abortion (Healy, Otsea and Benson, 2006; Campbell O.M.R. *et al.*, 2016) and gender-based violence services (Dennis *et al.*, 2019). Authors have also adapted, extended or extrapolated the signal function concept to measure different elements and domains of service provision such as readiness (Nesbitt *et al.*, 2013; Cranmer J. *et al.*, 2015).

At the same time, and throughout these various iterations, the concept of signal function measurement and the endorsed EmOC signal functions have been critiqued. Some raise concerns that EmOC signal functions oversimplify complex and nuanced processes of care and threaten to crowd out attention from other crucial areas of health facility performance, including routine care and quality of care more generally (Brenner *et al.*, 2015). Whilst the simplicity of signal functions is part of their appeal, some contend their simplicity portrays an inaccurate picture of what services are actually available throughout a country's health system (Cranmer J. *et al.*, 2015). The requirement that all signal functions actually be performed within a set time period to be classified as a Basic EmOC or Comprehensive EmOC facility, may be too difficult to achieve and discourage those working for improvement (Paxton *et al.*, 2006).

Such critiques have developed and evolved alongside broader changes in the maternal and newborn health landscape. Since the EmOC framework was introduced, there has been an absolute and a relative increase in facility births in LMIC settings, along with a reduction in maternal deaths and

changes in the epidemiology of maternal health (Campbell *et al.*, 2016). Newborn health is a much higher priority on the global health agenda following critical epidemiological work on newborn survival and stillbirth (Lawn, Cousens and Zupan, 2005; Lawn *et al.*, 2014; Blencowe *et al.*, 2016). As higher coverage of facility delivery has been achieved, there is overall greater attention to the quality of facility-based care along the continuum of care with interest in respectful care for women and newborns (Freedman *et al.*, 2014; Sacks, 2017), the overall experience of care that is received (WHO, 2016) and the importance of newborn health beyond survival (Lawn *et al.*, 2013; WHO and UNICEF, 2019). Data systems have evolved and are improving, with routine data increasingly complementing , and in some cases replacing, periodic surveys (Maina *et al.*, 2017; Bhattacharya *et al.*, 2019).

The economic and political environment has changed as well. The 1980s and 1990s were decades of structural adjustment and deep retrenchment for health sectors, especially in LMICs. Consequently, health strategies promoted by global actors typically sought to introduce streamlined vertical programs or isolated interventions, shunning investment in health systems more broadly (AbouZahr, 2003). If maternal mortality reduction depended on building health systems that could provide life-saving care to every woman who experienced an obstetric complication, then advocates for such a strategy needed to find ways to pierce the prevailing narrative of global development (Yamin and Maine, 1999). At the same time, human rights principles, especially in the evolving areas of women's rights and the right to health, challenged the economic orthodoxy of the era in which the *Guidelines* were developed. This opened up space in the development and global health sectors for greater investment in a health concern that had arguably received too little attention because it affected women (Kim, 1999). With the Millennium Development Goals (2000-2015) and then the Sustainable Development Goals (2015-2030), MNH gained greater attention even if the debates surrounding strategies to meet these goals continue to evolve.

The Re-Visioning Emergency Obstetric and Newborn Care (EmONC) project was led by a Steering Committee coordinated by the Averting Maternal Death and Disability (AMDD) program at Columbia University Mailman School of Public Health, and including UNICEF, UNFPA, WHO and the London School of Hygiene and Tropical Medicine (LSHTM). Re-Visioning EmONC aims to ensure that a revised obstetric and newborn care framework meets the needs and real-world conditions at the national and sub-national policy level and at the frontlines of health systems in LMICs at different stages of the obstetric transition.

Carrying out a meaningful revision of the signal functions requires reflection on the different narratives on signal functions that have emerged from different disciplines over the past few decades. For this review, we were interested in how both proposed changes to the signal functions have evolved and how different narratives have played a role in the conceptualisation and application of this approach to different areas of reproductive health. The review was intended to provide context and reflexivity as part of background work for the Re-Visioning EmONC project.

We conducted a literature review inspired by the meta-narrative approach following the Realist and Meta-narrative Evidence Syntheses: Evolving Standards (RAMESES) standards.

Our objectives were:

1. To review how different narrative traditions have developed and conceptualised signal functions, and identify the meta-themes behind these.
2. To draw insights into these different narratives and themes to inform future developments on signal functions.

METHODS

Meta-narrative

Meta-narrative review is a relatively new approach to literature review that selects and combines data from multiple sources, and compares and contrasts findings to build a rich picture – or

overarching narrative summary – of the topic from different perspectives (Gough, 2013). The principles of pragmatism, pluralism, historicity, contestation, reflexivity and peer review underpin the meta-narrative review approach, which involves six key stages: planning, iterative searches, mapping, appraisal, synthesis, and recommendations (Wong *et al.*, 2013a; Otte-Trojel and Wong, 2016). Through this iterative process, our methodology aimed to identify a core set of narrative traditions and a series of meta-themes. The narrative traditions are the main perspectives or lenses that appear in the literature and the meta-themes are the example storylines or arguments through which these narratives play out. Table 1 shows how we applied the principles of meta-narrative to this review.

1. **Planning phase:** We assembled a small team to discuss the approach, carry out the searches and mapping (XX, XX, XX and XX). We presented the review to the Re-Visioning EmONC Project Steering Committee and used this to refine review questions and define scope of the review. We registered our protocol with PROSPERO (ID number: CRD42021236111).

   Search phase: Following guidelines for meta-narrative review, the search phase included formal and informal searches to complete an iterative exploration of existing papers relevant to the research question (Gough, 2013; Wong *et al.*, 2013b). Initial informal searches were intended to explore diversity of perspectives and approaches on use of signal functions using the search term "signal functions" in PubMed. We then carried out formal systematic searches in April 2021 in Medline, Embase and Cinahl. Search phrases included keywords on signal functions or interventions for emergency or routine care for pregnant women and newborns. We did not restrict based on country of origin, article type, time period or language. Inclusion criteria were: empirical research, measurement or evaluations of existing signal functions for measuring facility-based care; theoretical critiques or commentaries of existing signal functions or the signal function approach; proposals of new or alternative signal functions; or approaches to measurement based on signal functions for facility-based reproductive health care. Whilst papers at any point along the reproductive

health continuum of care were considered, we were particularly interested in obstetric and neonatal care as these were the focus of the Re-Visioning EmONC project (see appendix/supplementary file for the example search strategy). We also hand searched references from the retrieved articles to identify relevant literature. Screening was independently carried out by XX and XX. We created and sent an anonymous survey to all 18 members of the Re-Visioning EmONC Project Steering Committee requesting that they share key papers they perceived as having shaped their thinking and views on signal functions (which could include grey literature). Following the initial systematic search and expert survey, we relied on citation tracking to ensure an iterative search approach in line with the recommended search methodology (Wong *et al.*, 2013b; Otte-Trojel and Wong, 2016). As we proceeded with the next steps of the review, we also requested members of the project steering committee send us further expert recommendations based on emerging themes.

2. **Mapping phase:** We started mapping at the screening stage to categorise and group papers and identify narratives and themes. During the screening, XX and XX met regularly to discuss different themes and categories for the papers. In these discussions, XX and XX found numerous papers where signal functions had been used or applied but not in ways that met the requirements for a more in-depth narrative synthesis (i.e. the paper used signal functions to measure facility-based care, but did not provide any substantive discussion or critique of the signal function approach). Subsequently, we developed a standardised tool to colour-code the papers. Red=exclude Grey=include for full text review Green=consider for meta-narrative synthesis (see appendix/supplementary file). All papers categorised as grey or green were retained for full text review. During full text review some papers were re-categorised from grey to green. Following full text review, all papers categorised as green were retained for further appraisal for the narrative synthesis. Papers categorised as grey were still considered relevant for the overall Re-Visioning EmONC Project and were reviewed fully and collated into summary tables by XX.

3. **Appraisal phase:** XX, XX and XX created a detailed data extraction form to capture data on how signal functions had been developed, conceptualised and theorised, and to extract relevant data. Papers categorised as green and retained for meta-narrative synthesis were reviewed in detail, discussed and entered into the customised data extraction form. SB, JT and SM agreed on the final subset of articles to include in the meta-narrative review with understanding that the iterative process of the review might require further scoping or inclusion of other articles based on citation chasing or expert recommendation. XX and XX met regularly to reflect, discuss and interpret.
4. **Synthesis phase**: XX and XX first began to identify themes at the mapping stage and continued during the process of appraisal, noting themes in a shared document. XX and XX met regularly to discuss emerging themes and began to group them into meta-themes. Once we had identified a selection of potential meta-themes, XX and XX followed a process of paradigm bridging (seeking commonalities in underlying conceptual and theoretical assumptions), paradigm bracketing (highlight differences in these assumptions), interplay (exploring tensions) and meta-theorising (exploring patterns that span conflicting understandings) (Greenhalgh *et al.*, 2005; Wong *et al.*, 2013b) to construct the final summary meta-themes.
5. **Recommendations phase**: We engaged with members of the project steering committee to interpret findings through ad hoc meetings throughout the course of the project.

RESULTS

We identified a total of 312 records from electronic searches of three databases and 17 papers from the expert survey from the project steering committee. After we removed 182 duplicates, we screened 147 titles and abstracts (XX and XX). Figure 2 shows the RAMESES-PRISMA diagram. The final meta-narrative synthesis contained 19 sources that included research papers, commentaries and reports or report chapters. Papers identified were published from between 1991-2022. Ten

were global in focus and two multi-country focus; one of the multi-country studies collected data from three countries (Uganda, Indonesia, India) and another carried out a secondary analysis of data from 13 countries in Africa, Asia and Latin America. The remainder of the papers were either research or secondary data analysis carried out on individual countries in Africa and Asia, including Malawi, Zambia, Kenya, India and Ghana. The focus of individual papers varied across the continuum from antenatal care, emergency obstetric care to postnatal care, abortion care and care of small and sick newborns, as well as one article on signal functions for sexual violence. Within the continuum of care, papers then focused in on routine or emergency obstetric and newborn care, a combination of both, or how the signal function approach related to reducing maternal mortality and measurement of obstetric and newborn care more broadly.

We identified three overarching narrative traditions and five meta-themes, described below in that order.

Narrative traditions

As early as the planning stage, we identified three broad narrative themes or traditions, which tended to dominate the lens by which signal functions were conceptualised and described 1) a clinical narrative 2) a health systems narrative and 3) a human rights narrative (Table 2).

1) **The clinical narrative** focused in on what clinicians in facilities should be doing and critiqued the signal functions in relation to their appropriateness as clinical measures and on how accurately they capture whether women and newborns received good quality clinical care. Papers within the clinical narrative were a combination of global guidelines or critiques within signal function compendiums, or special studies of a small sample of facilities describing how signal functions could be used or improved for more in-depth quality assessment, or to assess care in individual facilities.
2) **The health systems narrative** focused on what planners and managers were doing to describe and advance the system overall and tended to frame signal functions in terms of

measurability and representativeness. Papers published within the health systems narrative were usually attempting to develop or use signal functions to understand status of facility-based care in multiple countries or districts or how to apply the signal functions for programmatic use, usually through analysis of survey data (either primary data collection or analysis of secondary data). The health system narrative also used signal functions to characterise facilities in combination with geographical information system data to calculate physical proximity to the population requiring care.

3) **The human rights narrative** framed emergency obstetric care as a human right; signal functions acted as a means to identify where the system was failing women in order to demand accountability from the system. Those papers identified as belonging to the human rights narrative tended at their core to frame EmONC within human rights principles overall and use signal functions as a means or to draw attention to and advocate for investment in reproductive health services.

In Table 2, we define the narrative traditions, including the main academic disciplines that tended to dominate these narratives, followed by practical examples of how these were then articulated in practice by those using the data (data end users). We found that these three narrative themes could overlap and intersect and be complementary, however, they could also come into conflict. Out of 19 published papers, we found more papers from the clinical (n=10) and health systems narratives (n=15) than the human rights narrative (n=5), but some papers spanned more than one narrative tradition. The health systems narrative most frequently overlapped or bridged narratives with both clinical and human rights, whereas this did not occur with the clinical and human rights narratives. Both the clinical and health systems narrative contained more research articles (n=12) and systematic reviews (n=2), while the human rights narrative contained more commentary or opinion pieces (n=3) Table 3 summarises the papers included in the review and their respective narrative tradition(s).

Synthesis of meta-themes

Our synthesis process identified five key meta-themes that dominated critiques of signal functions. Below we present each meta-theme by describing the theme and the main critique and how different papers proposed to respond to this critique.

Meta-theme 1: Framing the boundaries

The first meta-theme was about the extent and boundaries of health topics addressed by the set of signal functions and whether they should go beyond emergency obstetric care. See Figure 3 for a visual depiction of the timeline of the different proposed signal functions.

Critiques

The first set of EmOC signal functions published in 1997 (WHO, UNICEF, and UNFPA, 1997) applied a simple logic of using a subset of eight functions to signal the ability of health facilities to treat the obstetric complications that most commonly led to maternal death. These signal functions were partially derived from the 1991 WHO guidelines on essential elements of obstetric care (WHO, 1991) which, as a clinical guideline document, contained detailed content on the monitoring, prevention and neonatal care elements of obstetric care overall. The signal functions in the 1997 Guidelines shifted attention towards complications and emergency obstetric care elements and focused in on emergency care in the labour and delivery room (basic), and obstetric surgery (comprehensive), (WHO, UNICEF, and UNFPA, 1997). It excluded neonatal care and surgery related to tubal ligation as they were not directly linked to maternal mortality. In contrast to longer checklists or other indicator sets, the limited number of signal functions helps to distil and synthesise a manageable set of information for the purpose of assessing health facility capacity (Dennis *et al.*, 2019) .

Over the subsequent decades, authors from different viewpoints have critiqued and discussed how the original (1997) and revised (2009) signal functions could cover a wider range of reproductive health topics. There has been an ongoing debate on how to frame the boundaries of the

reproductive health topics that signal functions can and should cover, including antenatal care, abortion care, newborn health, postnatal care and elements of routine care.

Suggested responses to the critique

Adding newborn signal functions: From EmOC to EmONC

Implementation experts and researchers working in child health, often from a clinical paediatric and epidemiology narrative lens, began advocating for greater coordination of maternal and newborn services (Martines *et al.*, 2005) long before a newborn resuscitation indicator was added to the set of signal functions in the revised EmOC Guidelines in 2009 (WHO *et al.*, 2009). As post-neonatal infant and child deaths began to decline, newborn deaths began to constitute a greater proportion of under five deaths overall. Newborn health advocates highlighted the scale of preventable newborn mortality and the lack of attention to newborns within mother and child survival strategies (Lawn, Cousens and Zupan, 2005; Martines *et al.*, 2005). Unlike child health interventions (such as immunisation and management of diarrhoea), newborn interventions were similar to maternal interventions in the sense that they could not easily be measured via the dominant household survey approaches (such as the Demographic and Health Surveys) (Maine, McCarthy and Ward, 1993). The first set of proposed newborn functions to go beyond neonatal resuscitation, however, was not published until 2012 (Gabrysch S *et al.*, 2012). Following the launch of the Every Newborn Action Plan (ENAP) (Lawn *et al.*, 2014) and the associated metrics group, which galvanised sustained attention to the data and measurement gaps for newborn health, including stillbirth (Moxon *et al.*, 2015), it was argued that the signal functions proposed by Gabrysch *et al* in 2012 al did not sufficiently cover interventions for small and/or sick newborn care (Moxon S.G. *et al.*, 2019). Later authors have highlighted that key functions for newborns are maternal interventions that occur prior to birth (e.g. antenatal corticosteroids for preterm labour or caesarean section) (Mony *et al.*, 2015; Moxon S.G. *et al.*, 2019; Narayanan *et al.*, 2019) questioning whether obstetric and newborn signal functions can ever be viewed separately.

The proposed approaches to add newborn signal functions came from both a clinical and health systems narrative lens, building a justification from a broad array of epidemiological work (Lawn, Cousens and Zupan, 2005; Lawn *et al.*, 2014), which contrasts from the human rights and health systems narrative (Yamin and Maine, 1999; Freedman, 2001) from which the obstetric signal functions were originally formulated. To this date, only one newborn signal function (newborn resuscitation) has been formally added to the set of nine endorsed signal functions (WHO *et al.*, 2009), although an explicit aim by the end of the Re-Visioning EmONC Project was to include a new set of newborn signal functions which will be formally adopted alongside the obstetric signal functions.

Defining abortion signal functions

Several authors made a compelling argument to measure abortion care using signal functions. Rather than critiquing signal functions, they saw an opportunity to extend the signal function approach to properly capture interventions that could prevent abortion-related mortality given that the existing signal functions only captured vacuum aspiration (Healy, Otsea and Benson, 2006; Campbell O.M.R. *et al.*, 2016; Owolabi O.O., Biddlecom A., and Whitehead H.S., 2019). (Healy, Otsea and Benson, 2006). Proposed abortion-related signal functions included services for induced abortion and contraceptive services to prevent unwanted pregnancy. These proposals for abortion signal functions were voiced through a health systems and a human rights narrative lens. See Box 1 for more details on development of abortion signal functions.

Incorporating routine care signal functions

Researchers within the health systems and clinical narratives have frequently called for routine signal functions (key services that all women and their newborns should receive) “in view of the emerging consensus on the continuum of care linking mother and child, and the links between routine care and care for complications” p2 (Gabrysch S *et al.*, 2012). From a health systems narrative, Gabrysch proposed a parsimonious six routine functions, while Brenner et al (2015) – from

a more clinical perspective - proposed over 50 routine antenatal and postnatal care processes as signal functions intended for clinical observation (Gabrysch S *et al.*, 2012; Brenner *et al.*, 2015). Authors that have proposed or worked with proposed newborn signal functions (Gabrysch S *et al.*, 2012; Brenner *et al.*, 2015; Mony *et al.*, 2015; Moxon S.G. *et al.*, 2019) mostly detail routine care signal functions based on the argument that women and newborns will require these interventions in addition to the care for complications. Contention on the inclusion of routine signal functions has persisted within the health systems narrative and even advocates of routine care signal functions note "…one might argue that by including preventive, routine care and inpatient care measures, the framework ceases to be an "emergency framework"… p11 (Moxon S.G. *et al.*, 2019). The blurring between routine and emergency care is also reflected in the newly proposed antenatal and postnatal care signal functions (based on literature and expert consensus), which include preventive and screening services (McCauley, Kirsty Lowe, *et al.*, 2022; McCauley, K Lowe, *et al.*, 2022).

In summary, this first meta-theme found criticisms or discussion of the EmOC signal functions (Figure 1a) tending to identify the need to cover further areas of health. In response, mostly authors propose adding signal functions or creating parallel sets of signal functions. We found the highest number of papers proposing signal functions for newborn health and for abortion care. In addition, some authors have highlighted the benefits of the signal function approach, but criticised signal functions for focusing acutely on complications in childbirth and failing to cover routine care that is required by all women and newborns. These arguments for different sets of signal functions are often articulated through different and contrasting narrative lenses; framing the boundaries of the breadth of topics that the signal functions should cover is a tension that persists to date.

Meta-theme 2: Moving beyond clinical capability

The second meta-theme focused on whether broader dimensions of facility care, such as the environment and infrastructure, could be measured as signal functions and even whether proxies of effective coverage could be built from the signal function concept.

Critiques

The original EmOC signal functions published in 1997 (WHO, UNICEF, and UNFPA, 1997) focused on eight functions to signal the ability of health facilities to treat the obstetric complications that most commonly led to maternal death. The addition of a newborn signal function in 2009 was intended to represent a main cause of newborn mortality in the perinatal period. All of these signal functions are built around specific clinical interventions delivered at the facility level in the labour and delivery room. Many authors questioned whether measuring the application of these interventions was enough, and whether additional dimensions of facility care could be included as signal functions in order to assess elements of an enabling environment as part of the set of signal functions.

Suggested responses to the critique

Gabrysch *et al* proposed signal functions that include enabling conditions like availability of 24-hour staffing, water and sanitation infrastructure, communication and referral (Gabrysch S *et al.*, 2012). Following this vein, authors who have proposed signal functions for abortion care have included domains like infrastructure, human resources, communication, and referral as well (Campbell O.M.R. *et al.*, 2016). Using a signal functions approach to assess sexual violence services, Dennis *et al* also proposed signal functions for broader services (such as counselling) and infrastructure (such as privacy) to examine the physical accessibility of sexual violence services. Dennis *et al*, from both the health system and human rights narrative, shows the overlap of areas of reproductive health with other sectors e.g. security (Dennis *et al.*, 2019). Healy and colleagues included assessment of socio-political and legal context as part of the assessment of safe abortion services (Healy, Otsea and Benson, 2006).

A health systems narrative approach by Nesbitt and colleagues attempted to address this limitation of signal functions by creating composite indicators built on signal functions. They used the signal functions to assess quality of care across routine and emergency maternal and newborn functions and attempted to estimate effective coverage looking at issues beyond the clinical – non medical

aspects, referral, human resources – and create composite quality categories based on the broader range of signal functions proposed by Gabrysch (Nesbitt *et al.*, 2013).

Most recently from both a clinical and health systems narrative McCauley and colleagues identified signal functions for antenatal and postnatal care. They took a continuum of maternal and newborn health care approach and a more holistic view of the potential of signal functions to consider to measure interventions that can reduce mortality and morbidity. Their broader set of postnatal and antenatal care signal functions proposed a shift towards a more comprehensive definition of maternal morbidity that would capture a positive pregnancy and labour experience and includes social morbidity (substance abuse and intimate partner violence) and mental health (McCauley, Kirsty Lowe, *et al.*, 2022; McCauley, K Lowe, *et al.*, 2022).

In summary, this second meta-theme found that authors from all narratives were interested in exploring the potential of signal functions to measure more about the environment or interventions that may be more broadly related to the well-being of women and their newborns. Attempts to build more complex composite indicators from signal functions have also been trialled to try to understand broader dimensions of the environment and whether the care was delivered effectively.

Meta-theme 3: Capturing the woods versus the trees

The third meta-theme relates to the extent of granularity and the conflict between a broader health systems view versus a detailed facility level picture.

Critiques

Signal functions are usually measured by a simple count of whether or not the facility performed the function in a specified timeframe (usually as a question to the in-charge and/or double checked in a register). This approach has been widely acknowledged as helpful for monitoring trends over time and assessing improvement or deterioration in services. It has also been found useful in understanding geographical access to services (especially in combination with geospatial data) and

access disparities and hererby supporting advocacy for investment in obstetric care (Maine, McCarthy and Ward, 1993; Bailey P. *et al.*, 2006; Paxton *et al.*, 2006; Campbell O.M.R. *et al.*, 2016; Dennis *et al.*, 2019). An area of diverse opinion, however, has been how to create a balance between a broader health system level focus and a closer granular focus on facility level measures of clinical care. This is frequently an area of contestation between the clinical narrative in contrast to the health systems and human rights narratives.

At the close of the Millennium Development Goal era (2000-2015), despite an increase in the number of facility births and reductions in mortality, epidemiological data did not show the expected improvements in maternal and newborn outcomes. Subsequently, those working in maternal and newborn health increasingly focused on the contribution of quality of care to preventable death. With many countries moving through different phases of the obstetric transition, there is an increased interest in interventions and care that can reduce morbidity as well as mortality. As clinical quality improvement tools and initiatives became more frequently designed and applied, many - from both a health systems and clinical lens – critiqued the central concept of signal functions to act as a proxy measure stating that "signal function[s]…do not directly reflect client experience with health services or their health outcomes" p 112 (Owolabi O.O., Biddlecom A., and Whitehead H.S., 2019). In the absence of individualised data, those assessing facilities wanted more detailed and granular Information to better understand quality of care.

Suggested responses to the critique

Brenner identified the clinical presentations of major direct causes of maternal and newborn mortality to further classify and select the most relevant routine care indicators based on medical acuteness (Brenner *et al.*, 2015). These were intended to complement the more broadly framed clinical process indicators proposed by Gabrysch et al (2012). Designed specifically for direct clinical observation of quality of routine care at the maternal-newborn health junction (which comprises labour, delivery and immediate postnatal), Brenner's proposed routine signal functions attempt to

bring the signal function approach from the health system functionality to the level of quality of care at the facility. Cranmer's clinical cascade approach (Cranmer J. *et al.*, 2015), another example of a the clinical narrative, breaks down the signal functions to assess capacity to provide a particular intervention by addressing the ability to manage each step of a clinical condition – identify, treat and modify/manage. When this clinical cascade is added to quantify practical readiness, the cascade explicitly identifies "the interdependent relationship among resources" p14 and that non-performance of a clinical intervention can be due to a wide array of interrelated factors therefore not just measuring whether a facility is ready, but its ability to manage all the stages of a clinical condition (Cranmer J. *et al.*, 2015). In their work, Cranmer et al found a consistent drop-off in facility readiness moving from one clinical stage to the next (i.e. from identifying to treating a specific condition), concluding that the signal functions approach could consistently overestimate the capacity of facilities to provide appropriate care (Cranmer J. *et al.*, 2015).

In summary, there is a clear conflict between narratives in this meta-theme. As measurement experts searched for clinical quality improvement tools to better understand quality of care, the clinical narrative found the signal functions approach to be limiting. Within the human rights narrative, in contrast to the clinical narrative, the exactitude of the measurement is framed as less important than the overarching picture of holding systems accountable for providing services for childbirth. In the human rights narrative, signal functions and the EmOC framework provide a system-wide analysis to characterise what health facilities could do in order to flesh out key content of the right to health, and to place responsibility on government as the duty bearer rather than locating the responsibility on individual providers, facilities or women (Yamin and Maine, 1999; Freedman, 2001). There is a degree of overlap and cohesion between health systems and human rights narratives when signal functions are used to characterise facilities by levels of care, in combination with GIS data, showing the physical proximity of facilities to the population and thus arguing for accountability from the system to provide care.

Meta-theme 4: Grouping signal functions

The fourth meta-theme relates to how signal functions have been arranged to act as proxies of different levels of service provision.

Critiques

The original EmOC signal functions were grouped into two levels -*basic* and *comprehensive* - roughly corresponding to health centre level (with nurse/midwives) and first referral level (with physicians) (Bailey P. *et al.*, 2006; Gabrysch S *et al.*, 2012) with the comprehensive level being defined by surgical capacity (e.g. caesarean section and blood transfusion) (Figure 1a). The concept of identifying the essential elements of obstetric care at the first referral (i.e. district hospital) level was introduced by WHO where the *first referral level* is the key level of health system focus for obstetric care in their original guidelines from 1991 (WHO, 1991).

Suggested responses to the critiques

In their proposed new signal functions, Gabrysch *et al* identified additional domains by adding – *general requirements* of any health facility where deliveries occurred, in addition to *basic* and *comprehensive* level (Gabrysch S *et al.*, 2012). Brenner and colleagues further developed the concept of routine care breaking this up into *risk assessment*, *risk monitoring* and *risk prevention* in their list of 51 routine care signal functions (Brenner *et al.*, 2015).

In proposing signal functions for sexual violence, Dennis et al defined levels as *core services* – (should be available whenever an individual presents to a health facility for services related to sexual assault), *immediate care* (time sensitive available to eligible individuals who present to a facility within zero to five days of a sexual assault), *delayed care and follow up care* (focus on managing unwanted pregnancy via terminations and testing and counselling for sexually transmitted infections (STIs). In this paper, *comprehensive care* is a facility able to provide core services, immediate care and delayed care and follow up (Dennis *et al.*, 2019) and also hinted at how signal functions can be

used to link to other systems/sectors, such as police and security. Analysing the data related to abortion services in Zambia, Campbell and colleagues synthesised the data to look at three different abortion scenarios for interpreting availability of signal functions in Zambia – Zambian *law scenario*, *best practice scenario* and *minimal scenario* (Campbell O.M.R. *et al.*, 2016).

Facilities not performing all functions may be classified as not fully functioning EmOC leading to an erroneous conclusion that they aren't able to provide any important life-saving or routine services. Paxton and colleagues, in their discussion of use of the signal function thus describe the proposed system of mapping performance of each signal function in each facility, with an option of classifying facilities as "*-1 or -2, -4 etc*" as a way of dealing with interventions that are inconsistently implemented in different settings (for example, assisted vaginal birth), or other interventions that may not be frequently performed (for example, due to low caseload) (Bailey P. *et al.*, 2006; Paxton *et al.*, 2006).

For newborns, Mony and colleagues built on the signal function concept to define basic emergency newborn care (BEmNC) and comprehensive emergency newborn care (*CEmNC)* (Mony *et al.*, 2015), however, Moxon and colleagues avoided basic and comprehensive language for their global survey on newborn interventions and used the terms *routine and essential care, special care* and *intensive care* to group levels of the different packages of interventions for newborns. This paper also defined a *transition level* – defined as interventions or services "that bridge the nexus between two defined levels of care" p9 (Moxon S.G. *et al.*, 2019) to allow for progressive realisation of services based on local context and resources. The question over how newborn signal functions should align with obstetric signal functions is not fully resolved in these papers.

In summary, this review found authors and narratives have expanded or reconceptualised these groupings of care differently recognising that different areas of care may lead to different nomenclature, different facilities are expected to do different things, or that circumstances might alter the expectations of facility capability.

Meta-theme 5: Measurement challenges

The fifth theme refers to some of the core measurement challenges that are identified with the use of signal functions, especially how to measure signal functions, and debates around the formulation of the process indicators built on signal functions (e.g. for benchmarking purposes).

Response to the Critiques

There is a substantial discussion on the minutiae of measurement, including debates on the way signal functions should be measured, including whether the facility should be asked if they can perform the intervention (theoretical) or whether they have performed the intervention within a specific timeframe (actual performance), and if so, over what length of time (Paxton, Bailey and Lobis, 2006; Paxton *et al.*, 2006; Nesbitt *et al.*, 2013).

Across the health systems narrative, a number of sources discuss the existing benchmarks and denominators for measuring availability of EmOC overall (the first of the process indicators calculated using signal functions in the Monitoring framework) (WHO *et al.*, 2009). When facilities have performed the seven signal functions of basic EmOC in the 3-month period before the assessment, the facility is considered to be a fully functioning basic EmOC facility; when it has performed all nine, it is classified as fully functioning comprehensive. For every 500,000 population, the minimum acceptable level is five fully functional EmOC facilities, at least one of which provides comprehensive care (WHO *et al.*, 2009). This benchmark was proposed by expert consensus (Paxton *et al.*, 2006). Papers reviewed proposed consideration of context specific benchmarks (Paxton *et al.*, 2006) and consideration of number of births as a more appropriate denominator as well as consideration other health system factors if interventions for other areas of care are included (Campbell O.M.R. *et al.*, 2016) (Mony *et al.*, 2015; Moxon S.G. *et al.*, 2019).

In summary, measurement issues often question how the endorsed EmOC signal functions should best be measured at the level of the facility. For benchmarking purposes, there is an ongoing

question as to whether proposed signal functions for other areas of care (abortion, newborn care) should be integrated or measured separately as standalone or parallel sets of signal functions as this affects which denominator should be used. Ultimately, the narrative lens and the intended end-user of the data, are instrumental in defining the parameters of the measurement.

DISCUSSION

To date, the nine endorsed EmOC signal functions have remained focused on emergency obstetric care with one newborn signal function added in 2009 (newborn resuscitation). This review has highlighted how three overarching narrative traditions – 1) clinical, 2) human rights and 3) health systems - have contributed to the debate and potential expansion of the endorsed EmOC signal functions to measure different time periods and domains along the continuum of care for reproductive health services. Through an iterative synthesis process and exploration of patterns of conciliation and conflict, this review summarised five meta-themes around the application and use and potential expansion of signal functions that were woven across these narrative traditions: i) framing the boundaries; ii) moving beyond clinical capability; iii) capturing the woods versus the trees; iv) grouping signal functions and v) measurement challenges. The review overall provides historical context and key critiques of the 2009 framework for the Re-Visioning EmONC Project and encourages a reflexive approach to thinking about the revision of the signal functions, emphasising the importance of considering the narrative lens and the data end user in the underpinning assumptions of the framework, and in revising the specific signal functions.

The history of emergency obstetric signal functions is rooted in the health systems and rights-based narratives with feminist and human rights thinkers playing an important role (Maine, McCarthy and Ward, 1993; Yamin and Maine, 1999; Freedman, 2001). Newborn signal functions are still not fully defined, but are strongly argued for in clinical and health systems narratives (Mony *et al.*, 2015; Moxon S.G. *et al.*, 2019; Narayanan *et al.*, 2019). These different narratives create some challenges for the integration of maternal and newborn signal functions given that they have been

conceptualised to date from different narrative lenses, which may have inadvertently created dissonance, with newborn signal functions constructed with more of a clinical lens. Contextually, there may have been perceived competition between maternal health and child health programmes over the decades, and newborn health advocates may also have had to tread carefully to ensure the newborn health agenda did not clash with hard won women's rights and abortion advocacy groups. These broader contextual factors may further have embedded the narrative framings over time, exacerbating conflict in the different positions. Understanding of these narratives may help reflect on this conflict and ensure that a congruous set of signal functions can be generated that covers the continuum of care more comprehensively, addressing the main causes of maternal and newborn death, as well as stillbirth. It is notable that in the recent article by McCauley et al (2022) the authors "do not make a distinction between… [signal functions] that are for the baby and those that are more specifically for the mother" (p9) due to the direct links between the health of the mother-baby dyad (McCauley, Kirsty Lowe, *et al.*, 2022).

The clinical narrative alone may find the signal function approach challenging, arguing that signal functions mask the deficit of health providers skilled in delivering the interventions. Just because an intervention was performed once, does not mean it was performed well or to the right women and newborns at the right time (Brenner *et al.*, 2015), as the fall off in the clinical cascade approach shows (Cranmer J. *et al.*, 2015). Nor does measuring signal functions generate information about the experience of care received. Positive and negative critiques of signal functions as an approach have been come into conflict between granular health facility focus, health system focus and an even broader accountability focus. The tension found between those arguing for clinical quality tools and broader health systems measurement is not unique to EmONC and this review found clear conflict between the clinical narrative and the human rights narrative. Many argue that signal functions help the data user to understand the information in the context of the health system and that, in contrast to many indicator compendiums, it generates health system level data that is easy to use and interpret (Campbell O.M.R. *et al.*, 2016; Dennis *et al.*, 2019; Owolabi O.O., Biddlecom A., and

Whitehead H.S., 2019), and is part of their rationale for suggesting it is useful to extend to other areas of health care, such as abortion or sexual violence services. This health system narrative may be the bridging link where cohesion between the three narratives can be found and the most helpful framing for signal functions into the future.

Implications of findings

The measurement of signal functions as a health systems tool does not preclude more detailed clinical quality measurement (e.g., studies including clinical observation) using more complex and detailed quality of care indicators, or even individualised data at the facility level. Furthermore, a detailed granular picture (like the identify, treat, modify/manage model proposed by Cranmer *et al*) can be derived from the signal function concept, but through the application of detailed special studies at the facility level. Signal functions might be better framed as a "red flag" approach for regular health system planning and monitoring, lending a health system level language for emergency obstetric and newborn care service provision. As data systems ideally move away from surveys alone towards more frequent use of routine data, it may be that more detailed measures on clinical quality can be collected through periodic and special surveys, as well as an increase in individualised data at the facility level. A combination of rights-based and health systems narrative may demonstrate how signal functions can be used for accountability as well as health system monitoring purposes (see Table 2 for examples of signal function data end use). The signal functions are only one part of the EmOC monitoring framework and other process indicators in the framework could be added or amended to better capture elements of the experience of care at the facility level.

In response to the line of critique on newborn signal functions and the need for a shift from EmOC to EmONC, the Re-visioning EmONC project has proposed a full set of newborn signal functions for measuring availability of inpatient care for small and/or sick newborns. Adding these newborn signal functions (or indeed other elements of reproductive health) requires consideration of the grouping of levels of care and the benchmarking for measuring availability overall. It is clear that a revisit of

the population based benchmark is required as newborn signal functions are added with consideration of the volume of births in the facility (Allen, Opondo and Campbell, 2017). Whilst some logical levels of care groups may need to be made for the framework overall, there may be ways this can also be dealt with in different contexts and settings at analysis level. For example, the use of an ideal and minimal scenario as has been done by Campbell and colleagues (Campbell O.M.R. *et al.*, 2016), or by achieving a mean number of functions (rather than an all or nothing approach). Some of the unique challenges for abortion signal functions are discussed further here (See Box 1).

Limitations

Reflexivity statement

The Re-Visioning EmONC Project is funded by the Bill and Melinda Gates Foundation through a grant to the Averting Maternal Death and Disability (AMDD) programme at Columbia University Mailman School of Public Health. Project work has been led by a Steering Committee and coordinated by AMDD and includes UNICEF, UNFPA, WHO and LSHTM as partners. Some authors of this review are part of the Project Steering Committee (XXX XXX, XX, XXX). Authors of this review, including XXX, XXX and XX have published previously on signal functions and are authors on the papers included in this review. Involvement in the field of measurement and having written and worked with signal functions previously does place the authors in a unique position to undertake this review, but also introduces a potential for bias interpretations based on our own positionality and professional narratives. In carrying out the scoping, mapping, appraisal and XXX stages of this review, XX and XX attempted to maintain focus on the review objectives and to give equal weight to all the papers and to ensure frequent discussion and reflection on our positionality was maintained throughout.

Our synthesis of the narratives and the subsequent storyline is limited by the material that is published, which creates its own bias subset of narratives. Whilst we strived for diversity and a broad range of narrative lenses, we recognise that this type of review often excludes the voices of those implementing and using these monitoring tools at the country level who may not publish their

views or experiences. What emerges in the literature is weighted towards the global perspective and only the addition of more grey literature or additional data collection could bring the voice of national perspectives more strongly to the review. To capture the extent of the narratives, the review would need to capture meeting minutes and discussions, as well as grey literature. We made efforts to include grey literature, but recognise that our grey literature search relied mainly on expert recommendation and is subsequently limited. Another approach may be to take a more historical lens and/or incorporate more grey literature including correspondence, qualitative interviews and other more diverse evidence sources.

In a pure meta-narrative review, a research tradition is the unit of analysis (Greenhalgh *et al.*, 2005; Wong *et al.*, 2013b; Otte-Trojel and Wong, 2016). For this review, we assumed that the topic area was unlikely to generate substantive theoretical discourses with linked empirical research in which successive studies are included by preceding inquiries. However, we did find sub-categories of approaches and narrative traditions that have developed over the past few decades that can be mapped to help us understand the different perspectives. For this reason we have used the term *meta-narrative inspired review*.

Finally, we limited the scope of our review to look at evolving narratives on signal functions to measure facility-based health services. Signal functions, however, are only one part of the EmOC monitoring framework and the eight accompanying process indicators present a broad array of measurement challenges that are not reviewed or discussed here. To have a comprehensive discussion of the all the measurement challenges that pertain to EmOC monitoring would require a broader scope with a more detailed discussion of the methodological challenges of measuring emergency obstetric and newborn care.

CONCLUSION

The EmOC signal functions, as part of the original (1997) and revised (2009) EmOC framework, were designed as a simple approach to allow health system managers to visualise their EmOC services

within the health system; they also served as a means to hold systems accountable to provide the main interventions to avert maternal deaths. Driven by a combination of health system and human rights based approaches and organised by the patterns of facility use at the time, they were focused intentionally on emergency obstetric care. With rapidly evolving health systems and LMICs moving through different phases of the obstetric transition, the field of measurement is ever more complex. Improving measurement in the MNH field to move beyond coverage and service readiness and measure quality is necessary. Yet improving measurement in a way that meets the needs of people at different levels of the health system, with different needs and ability to respond to data, whilst avoiding an overburden of paperwork for health workers, adds to the challenge. Narratives on signal functions have evolved alongside this changing measurement landscape and are influenced by the concurrent global health politics. Health systems and clinical narratives have played a central role in discussion around the revision of signal functions, especially in advocating for newborn signal functions and increasing attention to quality of care in the revision overall. We found that the clinical narrative, and even measurement elements of the health system narrative, are sometimes in conflict with the signal function approach often seeking greater granularity and precision in measurement or steering towards clinical quality indicators. Maintaining the rights-based narrative whilst working in tandem with a more health systems driven agenda in the revision will be important to ensure that the parsimony and simplicity of a shortlist of key functions is maintained. Understanding of these narratives is helpful for a reconciliation of obstetric and newborn care signal functions and levels of care in a revised and integrated EmONC framework that will remain useful for programme managers into the future.

References

Abegunde, D. *et al.* (2015) 'Availability, utilization, and quality of emergency obstetric care services in Bauchi State, Nigeria', *International Journal of Gynecology & Obstetrics*, 128(3), pp. 251–255. Available at: https://doi.org/10.1016/j.ijgo.2014.09.029.

AbouZahr, C. (2003) 'Safe motherhood: a brief history of the global movement 1947-2002', *British Medical Bulletin*, 67, pp. 13–25. Available at: https://doi.org/10.1093/bmb/ldg014.

Allen, S.M., Opondo, C. and Campbell, O.M.R. (2017) 'Measuring facility capability to provide routine and emergency childbirth care to mothers and newborns: An appeal to adjust for delivery caseload of facilities', *PLoS ONE*, 12(10), p. e0186515. Available at: https://doi.org/10.1371/journal.pone.0186515.

Bailey P. *et al.* (2006) 'The availability of life-saving obstetric services in developing countries: An in-depth look at the signal functions for emergency obstetric care', *International Journal of Gynecology and Obstetrics*, 93(3), pp. 285–291. Available at: https://doi.org/10.1016/j.ijgo.2006.01.028.

Banke-Thomas, A. *et al.* (2016) *Assessing emergency obstetric care provision in low- and middle-income countries: a systematic review of the application of global guidelines*. Available at: https://www.tandfonline.com/doi/full/10.3402/gha.v9.31880 (Accessed: 23 February 2021).

Bhattacharya, A.A. *et al.* (2019) 'Quality of routine facility data for monitoring priority maternal and newborn indicators in DHIS2: A case study from Gombe State, Nigeria', *PLOS ONE*. Edited by A.N. Bazzano, 14(1), p. e0211265. Available at: https://doi.org/10.1371/journal.pone.0211265.

Blencowe, H. *et al.* (2016) 'National, regional, and worldwide estimates of stillbirth rates in 2015, with trends from 2000: a systematic analysis', *The Lancet Global Health*, 4(2), pp. e98–e108. Available at: https://doi.org/10.1016/S2214-109X(15)00275-2.

Bosomprah, S. *et al.* (2016) 'Spatial distribution of emergency obstetric and newborn care services in Ghana: Using the evidence to plan interventions', *International Journal of Gynecology & Obstetrics*, 132(1), pp. 130–134. Available at: https://doi.org/10.1016/j.ijgo.2015.11.004.

Brenner, S. *et al.* (2015) 'The Quality of Clinical Maternal and Neonatal Healthcare – A Strategy for Identifying "Routine Care Signal Functions"', *PLOS ONE*. Edited by Y.-S. Ho, 10(4), p. e0123968. Available at: https://doi.org/10.1371/journal.pone.0123968.

Campbell O.M.R. *et al.* (2016) 'Signal functions for measuring the ability of health facilities to provide abortion services: An illustrative analysis using a health facility census in Zambia', *BMC Pregnancy and Childbirth*, 16(1), p. 105. Available at: https://doi.org/10.1186/s12884-016-0872-5.

Campbell, O.M.R. *et al.* (2016) 'The scale, scope, coverage, and capability of childbirth care', *The Lancet*, 388(10056), pp. 2193–2208. Available at: https://doi.org/10.1016/S0140-6736(16)31528-8.

Cranmer J. *et al.* (2015) 'Beyond signal functions in global emergency obstetrics: Using a cascade model to improve clinical quality and guide national strategy', *International Journal of Gynecology and Obstetrics*, 131(SUPPL. 5), pp. E91–E92.

Dennis, M.L. *et al.* (2019) 'A new approach to assess the capability of health facilities to provide clinical care for sexual violence against women: a pilot study', *Health Policy and Planning*, 34(2), pp. 92–101. Available at: https://doi.org/10.1093/heapol/czy106.

Dominico, S. *et al.* (2022) 'A Comprehensive Approach to Improving Emergency Obstetric and Newborn Care in Kigoma, Tanzania', *Global Health: Science and Practice*, 10(2), p. e2100485. Available at: https://doi.org/10.9745/GHSP-D-21-00485.

Freedman, L.P. (2001) 'Using human rights in maternal mortality programs: from analysis to strategy', *International Journal of Gynaecology and Obstetrics: The Official Organ of the International Federation of Gynaecology and Obstetrics*, 75(1), pp. 51–60; discussion 61. Available at: https://doi.org/10.1016/s0020-7292(01)00473-8.

Freedman, L.P. *et al.* (2014) 'Defining disrespect and abuse of women in childbirth: a research, policy and rights agenda', *Bulletin of the World Health Organization*, 92(12), pp. 915–917. Available at: https://doi.org/10.2471/BLT.14.137869.

Gabrysch S *et al.* (2012) 'New signal functions to measure the ability of health facilities to provide routine and emergency newborn care.', *PLoS Medicine*, 9(11), pp. e1001340–e1001340. Available at: https://doi.org/10.1371/journal.pmed.1001340.

Gough, D. (2013) 'Meta-narrative and realist reviews: guidance, rules, publication standards and quality appraisal', *BMC Medicine*, 11(1), p. 22. Available at: https://doi.org/10.1186/1741-7015-11-22.

Greenhalgh, T. *et al.* (2005) 'Storylines of research in diffusion of innovation: a meta-narrative approach to systematic review', *Social Science & Medicine*, 61(2), pp. 417–430. Available at: https://doi.org/10.1016/j.socscimed.2004.12.001.

Healy, J., Otsea, K. and Benson, J. (2006) 'Counting abortions so that abortion counts: Indicators for monitoring the availability and use of abortion care services', *International Journal of Gynaecology and Obstetrics: The Official Organ of the International Federation of Gynaecology and Obstetrics*, 95(2), pp. 209–220. Available at: https://doi.org/10.1016/j.ijgo.2006.08.002.

Hunt, P (2006) *Water and the right to the highest attainable standard of health: Submission to OHCHR*. Available at: https://www2.ohchr.org/english/issues/water/contributions/srapporteurs/SRrighttohealth.pdf (Accessed: 13 March 2023).

Kim, J.Y. (1999) *Dying for growth: global inequality and the health of the poor*. Monroe: Common Courage Press (Series in health and social justice).

Lawn, J.E. *et al.* (2013) 'Beyond newborn survival: the world you are born into determines your risk of disability-free survival', *Pediatric Research*, 74(1), pp. 1–3. Available at: https://doi.org/10.1038/pr.2013.202.

Lawn, J.E. *et al.* (2014) 'Every Newborn: progress, priorities, and potential beyond survival', *The Lancet*, 384(9938), pp. 189–205. Available at: https://doi.org/10.1016/S0140-6736(14)60496-7.

Lawn, J.E., Cousens, S. and Zupan, J. (2005) '4 million neonatal deaths: When? Where? Why?', *The Lancet*, 365(9462), pp. 891–900. Available at: https://doi.org/10.1016/S0140-6736(05)71048-5.

Maina, I. *et al.* (2017) 'Using health-facility data to assess subnational coverage of maternal and child health indicators, Kenya', *Bulletin of the World Health Organization*, 95(10), pp. 683–694. Available at: https://doi.org/10.2471/BLT.17.194399.

Maine, D., McCarthy, J. and Ward, V. (1993) 'Guidelines for monitoring progress in the reduction of maternal mortality [a work in progress]'. UNICEF.

Martines, J. *et al.* (2005) 'Neonatal survival: a call for action', *The Lancet*, 365(9465), pp. 1189–1197. Available at: https://doi.org/10.1016/S0140-6736(05)71882-1.

McCauley, H., Lowe, Kirsty, *et al.* (2022) 'Essential components of postnatal care – a systematic literature review and development of signal functions to guide monitoring and evaluation', *BMC Pregnancy and Childbirth*, 22(1), p. 448. Available at: https://doi.org/10.1186/s12884-022-04752-6.

McCauley, H., Lowe, K, *et al.* (2022) 'What are the essential components of antenatal care? A systematic review of the literature and development of signal functions to guide monitoring and evaluation', *BJOG: An International Journal of Obstetrics & Gynaecology*, 129(6), pp. 855–867. Available at: https://doi.org/10.1111/1471-0528.17029.

Mony, P.K. *et al.* (2015) 'Availability of emergency neonatal care in eight districts of Karnataka state, southern India: a cross-sectional study', *BMC Health Services Research*, 1, p. 461. Available at: https://doi.org/10.1186/s12913-015-1126-3.

Moxon, S.G. *et al.* (2015) 'Count every newborn; a measurement improvement roadmap for coverage data', *BMC Pregnancy and Childbirth*, 15(2), p. S8. Available at: https://doi.org/10.1186/1471-2393-15-S2-S8.

Moxon S.G. *et al.* (2019) 'Categorising interventions to levels of inpatient care for small and sick newborns: Findings from a global survey', *PLoS ONE*, 14(7), p. e0218748. Available at: https://doi.org/10.1371/journal.pone.0218748.

Narayanan, I. *et al.* (2019) 'Facility readiness in low and middle-income countries to address care of high risk/ small and sick newborns', *Maternal Health, Neonatology and Perinatology*, 5(1), p. 10. Available at: https://doi.org/10.1186/s40748-019-0105-9.

Nesbitt, R.C. *et al.* (2013) 'Quality along the Continuum: A Health Facility Assessment of Intrapartum and Postnatal Care in Ghana', *PLOS ONE*, 8(11), p. e81089. Available at: https://doi.org/10.1371/journal.pone.0081089.

Otte-Trojel, T. and Wong, G. (2016) 'Going Beyond Systematic Reviews: Realist and Meta-Narrative Reviews', *Studies in Health Technology and Informatics*, 222, pp. 275–287.

Owolabi O.O., Biddlecom A., and Whitehead H.S. (2019) 'Health systems' capacity to provide post-abortion care: a multicountry analysis using signal functions', *The Lancet Global Health*, 7(1), pp. e110–e118. Available at: https://doi.org/10.1016/S2214-109X%2818%2930404-2.

Paxton, A. *et al.* (2006) 'Global patterns in availability of emergency obstetric care', *International Journal of Gynecology & Obstetrics*, 93(3), pp. 300–307. Available at: https://doi.org/10.1016/j.ijgo.2006.01.030.

Paxton, A., Bailey, P. and Lobis, S. (2006) 'The United Nations Process Indicators for emergency obstetric care: Reflections based on a decade of experience', *International Journal of Gynecology & Obstetrics*, 95(2), pp. 192–208. Available at: https://doi.org/10.1016/j.ijgo.2006.08.009.

Sacks, E. (2017) 'Defining disrespect and abuse of newborns: a review of the evidence and an expanded typology of respectful maternity care', *Reproductive Health*, 14, p. 66. Available at: https://doi.org/10.1186/s12978-017-0326-1.

WHO (1991) ‘1991 WHO Essential elements of obstetric care at first referral level.pdf’.

WHO *et al.* (2009) *Monitoring emergency obstetric care: a handbook*. Available at: https://www.who.int/publications-detail-redirect/9789241547734 (Accessed: 21 October 2022).

WHO (2016) *Standards for improving quality of maternal and newborn care in facilities*. Geneva: World Health Organization. Available at: https://apps.who.int/iris/handle/10665/330824 (Accessed: 3 November 2022).

WHO (2018) ‘Joint state on the definition of skilled healht personnel providing care during childbirth: the 2018 joint statement by WHO, UNFPA, UNICEF, ICM, ICN, FIGO and IPA’.

WHO and UNICEF (2019) *Survive and thrive: transforming care for every small and sick newborn*. Available at: https://www.who.int/publications-detail-redirect/9789241515887 (Accessed: 7 April 2023).

WHO, UNICEF, and UNFPA (1997) *Guidelines for monitoring the availability and use of obstetric services*. Available at: https://www.publichealth.columbia.edu/sites/default/files/pdf/unguidelinesen.pdf (Accessed: 21 October 2022).

Wong, G. *et al.* (2013a) ‘RAMESES publication standards: meta-narrative reviews’, *BMC Medicine*, 11(1), p. 20. Available at: https://doi.org/10.1186/1741-7015-11-20.

Wong, G. *et al.* (2013b) ‘RAMESES publication standards: meta-narrative reviews’, p. 15.

Yamin, A.E. and Maine, D.P. (1999) ‘Maternal Mortality as a Human Rights Issue: Measuring Compliance with International Treaty Obligations’, *Human Rights Quarterly*, 21(3), pp. 563–607.

Figure 1a. Emergency obstetric care (EmOC) signal functions in 2009 handbook on monitoring emergency obstetric care

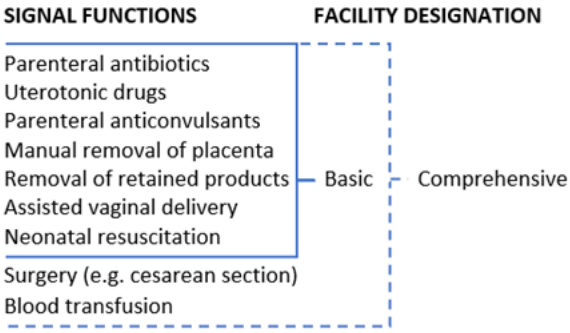

Figure 1b. Major obstetric complications and corresponding signal functions**Major complication**	**Corresponding signal functions**
Haemorrhage	***Ante-partum:*** Blood transfusion Surgery (e.g. caesarean section) ***Post-partum*** Uterotonic drugs Blood transfusion Manual removal of the placenta Removal of retained products Surgery (hysterectomy) for uterine rupture
Prolonged or obstructed labour	Assisted vaginal delivery Surgery (caesarean section) Uterotonic drugs Neonatal resuscitation
Postpartum sepsis	Parenteral antibiotics Removal of retained products Perform surgery for pelvic abscess
Complications of abortion	***For haemorrhage*** Blood transfusion Removal of retained products ***For sepsis*** Parenteral antibiotics Removal of retained produces ***For intra-abdominal injury*** Parenteral antibiotics Blood transfusion Surgery
Pre-eclampsia or eclampsia	Parenteral anticonvulsants Neonatal resuscitation Surgery (e.g. caesarean section)
Ectopic pregnancy	Surgery Blood transfusion
Ruptured uterus	Surgery Blood transfusion

	Parenteral antibiotics
Newborn distress (intrapartum)	Newborn resuscitation Surgery (caesarean section

Figure 2. RAMESES-PRISMA Diagram. RAMESES, Realist and Meta-narrative Evidence Syntheses: Evolving Standards; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses

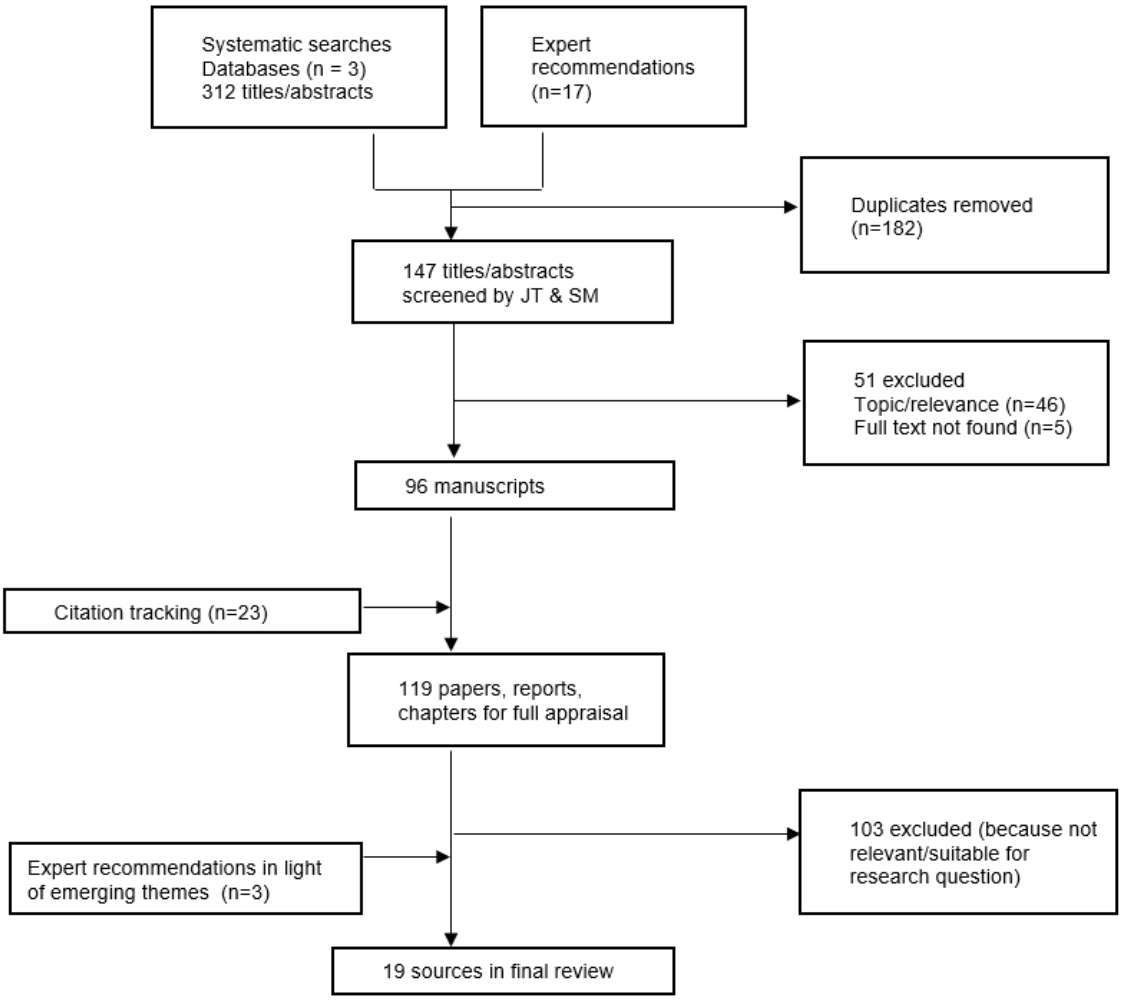

Figure 3. A timeline of signal functions from 1986 to present

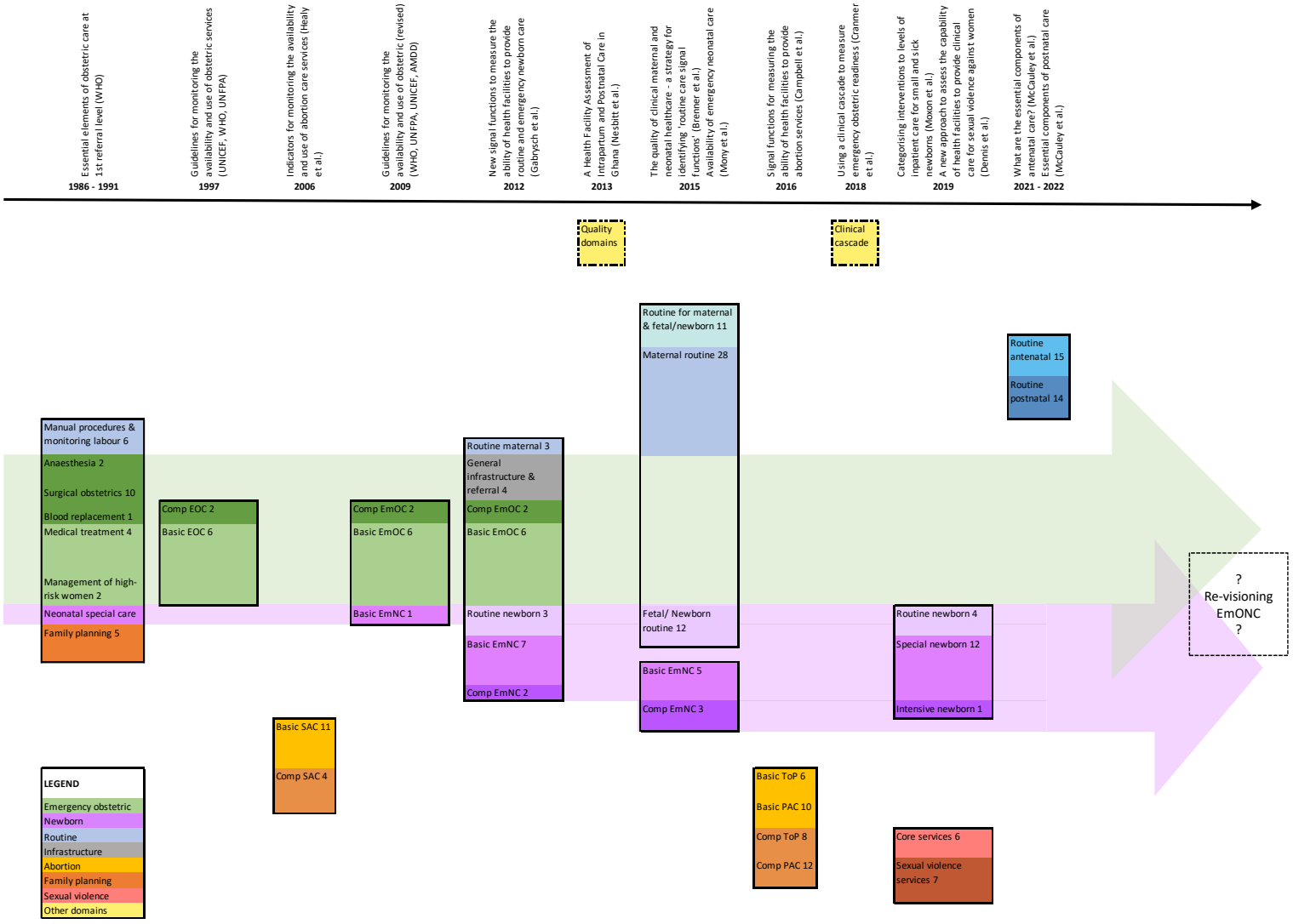

Table 1. Application of principles of meta-narrative to this review

Principle	**Definition**	**Application in this review**
Pragmatism	The review should include what makes sense for the intended audience to promote sense-making	The Re-Visioning EmONC project steering committee and relevant working groups were actively involved in defining the research questions. The pragmatic need to answer the research questions will ensure careful attention to evaluating the evidence to provide context to the revision of the EmONC framework.
Pluralism	The topic is explored from multiple perspectives and the tensions should be exposed	Members of the review team come from different disciplinary backgrounds and have different field experience bringing different paradigmatic viewpoints to understanding the literature. Evaluating included literature based on its on strength within its own tradition contributes to a pluralistic view of the subject.
Historicity	The review explores how the different approaches or traditions have evolved over time	Key literature, including commentaries, editorials, that have marked the evolution of the signal functions approach over the last 30 years will be explored to ensure that the review contextualises how the measurement approach itself is understood, interpreted and applied in practice.
Contestation	Conflicting data from different traditions should be explored to generate higher order insight	Contestation or differing perspectives on measuring availability of EmONC and signal functions are retained.
Reflexivity	Reviewers continually reflect (both individually and as a team) on the emerging findings	A culture of critical reflexivity in which the review team challenges its own assumptions and interpretations. The diversity in team members' professional backgrounds should help to promote reflection and cross-disciplinary thinking.
Peer review	Emerging findings should be discussed with an external audience	As part of the wider revisioning EmONC project, meetings with the project working group will be an inherent component of the review at various stages allowing for reflection and further analysis as the review progressed. A final draft was shared with external colleagues representing different narrative traditions for discussion and peer review.

Table 2. Summary of narrative traditions identified for this review

Narrative tradition	Academic disciplines	Scope of narrative tradition	Example of narrative tradition in practice (e.g., by data end user)
Clinical narrative	Obstetrics, paediatrics, neonatology, midwifery, nursing, clinical medicine	The clinical narrative frames the signal functions in relation to their appropriateness as clinical measures of facility capability especially in relation to averting mortality (and morbidity).	In practice, the data end user within the clinical narrative has proposed amendments to the signal functions that push them closer to measures of clinical quality, usually describing the signal functions as too general, too reductive, or even inconsistent from a clinical perspective. The clinical narrative also identifies or proposes additional signal functions to represent the full continuum of care (Brenner *et al.*, 2015; Cranmer J. *et al.*, 2015; Moxon S.G. *et al.*, 2019; Narayanan *et al.*, 2019; McCauley, Kirsty Lowe, *et al.*, 2022)
Health systems narrative	Epidemiology, metrics/ measurement science, monitoring and evaluation	The health systems and measurement narrative is concerned with the measurability of the signal functions, the representativeness of the signal functions and how they can be used to advance health systems to reduce mortality and morbidity.	The WHO 2018 definition of skilled health personnel (competent health-care professionals) providing care during childbirth (often referred to as "skilled birth attendants" or "SBAs") requires that skilled health personnel can perform all nine emergency obstetric care (EmOC) signal functions as part of their working definition. This definition is used as a means of monitoring skilled health personnel skills to optimise the health and well-being of women and newborns in health systems in low- and middle-income settings (WHO, 2018).
Human rights narrative	Human rights law, activism, feminism, women's rights, child's rights, advocacy, equity	The human rights narrative frames availability of emergency obstetric services at health facilities as a rights-based issue and views the signal functions as a means to demand accountability from the system (rather than the individual provider or facility).	The UN Special Rapporteur on the right to the highest attainable standard of health has developed an analytical framework that unpacks the right to health and has used this framework (or aspects of it) in all his numerous general and country reports. It cites lack of access to emergency obstetric care (defined by performance of signal functions) as part of this framework (Hunt, P, 2006)

Table 3. Summary of sources included in the review including narrative tradition(s) and article aims

	Author(s)	Year	Article title	Type of article	Narrative tradition(s)		Purpose/aim of article
1	Bailey P, Paxton A, Lobis S, Fry D.	2006	The availability of life-saving obstetric services in developing countries: An in-depth look at the signal functions for emergency obstetric care	Research article	Health systems, clinical	Emergency obstetric care	Use data from 1906 health facilities in 13 countries to examine how frequently the EmOC signal functions are performed. To examine what EmOC signal functions are frequently available, what are met, at which level etc. and to understand why signal are missing and what this can tell us and how governments/policy makers and programme managers can use this information for strengthening efforts.
2	Brenner S, De Allegri M, Gabrysch S, Chinkhumba J, Sarker M, Muula AS	2015	The quality of clinical maternal and neonatal healthcare – A strategy for identifying "routine care signal functions"	Research article	Health system, clinical	Intrapartum, immediate postpartum and postnatal	To identify a key set of MNH routine care process indicators or signal functions that can be used for in-depth quality assessments based on direct observation methods. To evaluate how well the indicator set performs in terms of applicability and information gain in a low-income setting (Malawi).
3	Campbell OMR, Aquino EML, Vwalika B and Gabrysch S	2016	Signal functions for measuring the ability of health facilities to provide abortion services: an illustrative analysis using a health facility census in Zambia	Research article	Health systems, human rights	Abortion care	To use a modified signal function approach for abortion care using existing multi-country facility survey instruments to measure the ability of health facilities to provide termination of pregnancy (TOP) and post abortion care (PAC) services. To apply this approach to secondary data from Zambia.
4	Cranmer JN, Dettinger J, Calkins K, Kibore M, Gachuno O, Walker D	2018	Beyond signal functions in global obstetric care: Using a clinical cascade to measure emergency obstetric readiness	Research article	Clinical	Emergency obstetric care	To conduct a cross-sectional observation study in Kenya to test a novel emergency obstetric readiness measurement approach – the clinical cascade - that can describe a facility's clinical readiness to manage obstetric emergencies based on Potter's hierarchy of need model of 1) Identify 2) Treat 3) Monitor/modify.

5	Dennis ML, Owolabi OO, Cresswell JA, Chelwa N, Colombini M, Vwalika BA, Mbizvo MT, Campbell OMR	2019	A new approach to assess the capability of health facilities to provide clinical care for sexual violence against women: A pilot study.	Research article	Health systems, human rights	Abortion care	To provide a set of signal functions that can be used to describe health facilities' readiness to provide clinical care for sexual violence. Pilot the approach in Central Province, Zambia to illustrate the potential insights that can be gained from using the proposed signal functions. Estimate women's physical proximity to health and police services to examine physical accessibility of multi-sectoral sexual violence services.
6	Freedman L	2001	Using human rights in maternal mortality programs: from analysis to strategy	Opinion	Human rights	Emergency obstetric care	Seminal article that forms a justification for why human rights is relevant to measurement of emergency obstetric care and signal functions. Articulates what applying human rights approach to guide actions for averting maternal death and disability means at the ground level and how human rights principles can be integrated at the clinical, facility management and policy levels.
7	Gabrysch S, Civitelli G, Edmond KM, Mathai M, Ali M, Bhutta ZA, Campbell OM	2012	New signal functions to measure the ability of health facilities to provide routine and emergency newborn care.	Research article	Health systems	Obstetric care and postnatal care, including newborn	To propose a set of signal functions that add routine maternal and newborn care and emergency newborn care functions to existing EmOC signal functions. Based on continuum of care approach between mother and newborn, and between routine care and complications.
8	Healy J, Otsea K, Benson J	2006	Counting abortions so that abortion counts: Indicators for monitoring the availability and use of abortion services	Research article	Health systems, human rights	Abortion care	To propose a set of signal functions to measure basic and comprehensive safe abortion care services. Also proposes a set of process indicators to measure safe abortion care at health systems level to develop a comprehensive approach to measure the implementation of safe abortion care interventions - including contraception and safe abortion.
9	Maine D, McCarthy J and Ward VM	1993	Guidelines for monitoring progress in the reduction of maternal mortality (a work in progress). Chapter XX on signal functions	Chapter of report/guidelines	Health systems	Emergency obstetric care	To provide guidelines describing the foundation of thinking in maternal mortality measurement, justification for the signal functions and process indicators and their programmatic use.

10	McCauley H, Lowe K, Furtado N, Mangiaterra V, van den Broek N	2021	What are the essential components of antenatal care? A systematic review of the literature and development of signal functions to guide monitoring and evaluation	Systematic review	Clinical, health systems	Antenatal care	To identify the essential components of antenatal care through literature review and to agree a new framework of signal functions for antenatal care and identify the essential equipment, drugs and consumables for implementation which can be used for the monitoring and evaluation through consensus-building workshops with international partners.
11	McCauley H, Lowe K, Furtado N, Mangiaterra V, van den Broek N	2022	Essential components of postnatal care – a systematic literature review and development of signal functions to guide monitoring and evaluation	Systematic review	Clinical, health systems	Postnatal care	To identify the essential components of postnatal care through literature review and to agree and develop signal functions for postnatal care and identify the essential equipment, drugs and consumables for implementation which can be used for the monitoring and evaluation of availability and quality through consensus-building workshops with international partners.
12	Mony PK, Jayanna K, Bhat S, Rao SV, Crockett M, Avery L, Ramesh BM, Moses S, Blanchard J.	2015	Availability of emergency neonatal care in eight districts of Karnataka state, southern India: a cross-sectional study.	Research article	Health systems, clinical	Emergency newborn care	To assess the status of emergency newborn care in eight districts of one state of India using signal functions built on those proposed by Gabrysch et al.
13	Moxon SG, Blencowe H, Bailey P, Bradley J, Day LT, Ram PK, Monet J-P, Moran AC, Zeck W, Lawn JE	2019	Categorising interventions to levels of inpatient care for small and sick newborns: Findings from a global survey	Research article	Health systems, clinical	Small and sick newborn care	To describe the findings of an online global survey of experts undertaken to categorise a list of newborn interventions to different levels of care and discussion on appropriateness as signal functions and potential alignment with obstetric care signal functions.
14	Narayanan I, Nsungwa-Sabiti J, Setyadewi L, Ronisiswatmo R, Thomas N, Kamalarathnam CN, Wembabazi JJ, Nakibuuka Kirabira V,	2019	Facility readiness in low and middle-income countries to address care of high risk/small and sick newborns	Research article	Clinical, health systems	Small and sick newborn care	To study readiness of neonatal units in referral hospitals in Uganda, Indonesia and India to provide care for small and sick newborns focusing on a sub-Saharan Africa country (Uganda) and two countries in Asia (India, Indonesia) using signal functions.

	Waiswa P, Data S, Kajjo D, Mubiri P, Ochola E, Shrestha P, Choi HY, Ramesethu J						
15	Nesbitt RC, Lohela TJ, Manu A, Vesel L, Okyere E, Edmond K, Owusu-Agyei S, Kirkwood BR, Gabrysch S.	2013	Quality along the continuum: A health facility assessment of intrapartum and postnatal care in Ghana	Research article	Health systems	Obstetric care and postnatal care, including newborn	To evaluate the quality of routine and emergency intrapartum and postnatal care, to estimate "effective" coverage of skilled birth attendance. Based on the EmOC signal functions and newborn signal functions but looks at issues beyond clinical care including non-medical aspects, referral, human resources. Creates composite quality categories based on broader range of signal functions including routine care and newborn care.
16	Owolabi OO, Biddlecom A, Whitehead HS	2019	Health systems' capacity to provide post-abortion care: a multicountry analysis using signal functions	Research article	Health systems	Abortion care	To assess the status of post abortion care (PAC) in multiple countries using a signal functions approach and document gaps in provision of PAC from health systems perspective.
17	Paxton A, Bailey P, Lobis S.	2006	The United Nations Process Indicators for emergency obstetric care: Reflections based on a decade of experience	Review/critique	Health systems	Emergency obstetric care	To review the experience with the EmOC process indicators, and examines whether the indicators serve their purpose of gathering and interpreting relatively accessible data to design and implement EmOC programmes.
18	World Health Organisation	1991	Essential elements of obstetric care at first referral level	Guideline	Clinical	Intrapartum and immediate postpartum care	To describe the results of a a technical working group convened in 1986 by WHO to define the essential obstetric care necessary for reduction of maternal mortality and morbidity and to describe the staff, training, supervision, facilities, equipment and supplies needed at the first referral level
19	Yamin A, Maine D	1999	Maternal mortality as a human rights issue: Measuring compliance with international treaty obligations	Opinion	Human rights	Emergency obstetric care	To explain how the UN indicators and signal functions for monitoring obstetric care can be used as a human rights tool to monitor a state's compliance with the right to health under various international treaties.

Box 1. Abortion signal functions: A brief history

Unsafe abortion is a major cause of direct maternal mortality – and management of abortion complications is listed as a basic emergency signal function in both the 1997 and 2009 formulations of the EmOC monitoring framework. In practice, abortion services are needed to intentionally terminate pregnancy (ToP) and to manage abortion complications (following spontaneous abortion, illegally induced abortion, or legally induced abortion) via post abortion care (PAC).

Three papers have proposed approaches to assessing provision of abortion services. As with all EmONC signal functions approaches, all three focused on services delivered via health facilities, but unlike EmOC signal functions, all include preventive dimensions via provision of post-abortion contraception and safe abortion.

In 2006, Healy and colleagues (Healy, Otsea and Benson, 2006) first proposed 11 signal functions to describe Safe Abortion Care (SAC) services with a further four staffing functions. They stratified these into basic and comprehensive levels based on gestation.

Ten years later, Campbell and colleagues (Campbell O.M.R. *et al.*, 2016) argued that Healy et al.'s approach would classify identical facilities differently depending the legal status of abortion in the country. They proposed an alternative version separating abortion signal functions into eight for TOP services and 12 for PAC services, also stratified into basic and comprehensive based on facility capability rather than gestation. PAC services were assumed to be needed 24/7, whereas TOP services could be scheduled.

In 2019, Owolabi and colleagues (Owolabi O.O., Biddlecom A., and Whitehead H.S., 2019) restricted their approach to post abortion care, but further adapted or modified Campbell et al.'s categorization, adding some signal functions and removing others. They had nine PAC functions, again divided into Basic and Comprehensive based on facility capability. They differed from Campbell in some assumptions, namely if a facility provided delivery services 24 hours seven days a

week (24x7), then it was assumed that staff were available also for PAC. Similarly, 24x7 caesarean section capability was assumed to mean availability of staff for comprehensive PAC.

All three papers belong mostly in the health system narrative tradition with some overlap with the human rights tradition (Table 3), especially when provoking discussion and consideration of legal status of abortion or rights to access care. Healy et al. proposed process indicators to measure SAC at health systems level; these largely paralleled EmOC indicators (Healy, Otsea and Benson, 2006). They then estimated SAC coverage in five countries. Campbell challenged the suitability of these (Campbell O.M.R. *et al.*, 2016). Between them the papers looked at abortion are readiness under different scenarios of legality and compared different national and subnational geographies. They also looked at geographic accessibility to such services.

Appendix/Supplementary files

Supplementary table 1. Search strategy

	EMBASE			MEDLINE			CINAHL	
1	ante?natal*.mp	56970	1	ante?natal*.mp.	34260	1	antenatal	14868
2	ante?partum*.mp	9112	2	ante?partum*.mp.	5428	2	antepartum	2002
3	pregnan*.mp	975694	3	pregnan*.mp.	970736	3	pregnan*	248,555
4	pre?natal*.mp	253777	4	pre?natal*.mp.	170797	4	prenatal*	56,071
5	birth*.mp.	498603	5	birth*.mp.	344811	5	birth*	123,184
6	intra?partum*.mp.	13521	6	intra?partum*.mp.	8153	6	Intrapartum*	5,272
7	matern*.mp	436829	7	matern*.mp.	314182	7	matern*	114,029
8	obstetric*.mp	184735	8	obstetric*.mp.	175459	8	obstetric*	57,081
9	peri?natal*.mp.	148349	9	peri?natal*.mp.	72324	9	perinatal*	34,272
10	deliver*.mp	1165927	10	deliver*.mp.	703728	10	deliver*	245,899
11	labo?r*.mp.	1231824	11	labo?r*.mp.	697595	11	Labor OR labour	61,375
12	mother*.mp.	313736	12	mother*.mp.	218546	12	mother*	107,686
13	post?partum*.mp.	80130	13	post?partum*.mp.	65472	13	Postpartum OR post-partum	30,466
14	post?natal*.mp.	156311	14	post?natal*.mp	107399	14	Postnatal* OR post-natal*	35,334
15	new?born*.mp.	668418	15	new?born*.mp.	759032	15	newborn* OR new-born* OR new born*	145,604
16	neo?nat*.mp.	374384	16	neo?nat*.mp.	272799	16	neonat* OR neo-nat* OR neo nat*	82,498
17	peri?partum*.mp.	8153	17	peri?partum*.mp.	4618	17	peripartum* OR peri-partum* OR peri parum*	1,858

18	signal function*.mp.	461	18	signal function*.mp.	350	18	signal function*	62
19	emergency obstetric care.mp.	991	19	emergency obstetric care.mp.	680	19	"emergency obstetric care"	374
20	(emergency obstetric and newborn care).mp	310	20	(emergency obstetric and newborn care).mp.	147	20	"emergency obstetric and newborn care"	71
21	Pregnancy Complications/ or Prenatal Care/ or Pregnancy/	634077	21	Pregnancy Complications/ or Prenatal Care/ or Pregnancy/	893552	21	(MH "Pregnancy+") OR (MH "Pregnancy, Unplanned") OR (MH "Pregnancy Outcomes") OR (MH "Pregnancy Complications+") OR (MH "Intrapartum Care+")	232,851
22	exp obstetric delivery/ or exp labor/	174971	22	Delivery, Obstetric/ or Labor, Obstetric/	55826	22	(MH "Prenatal Care") OR (MH "Prenatal Care (Iowa NIC)")	17,397
23	exp newborn/ or exp infant/	1017900	23	Infant, Newborn/	614340	23	(MH "Obstetric Emergencies") OR (MH "Delivery, Obstetric+") OR (MH "Obstetric Service") OR (MH "Obstetric Nursing") OR (MH "Obstetric Care+") OR (MH "Pregnancy Outcomes") OR (MH "Obstetric Patients") OR (MH "Perinatal Nursing") OR (MH "Obstetric Equipment and Supplies+") OR (MH "Surgery, Obstetrical+")	98,091

24	exp postnatal care/	7607	24	Postnatal Care/	5867	24	(MH "Infant, Premature") OR (MH "Infant+") OR (MH "Infant, High Risk") OR (MH "Infant, Very Low Birth Weight") OR (MH "Infant Death+") OR (MH "Infant, Newborn+") OR (MH "Newborn Care (Saba CCC)") OR (MH "Newborn Care (Iowa NIC)")	263,877
25	exp emergency health service/ or exp maternal health service/ or exp maternal care/	157185	25	Emergency Medical Services/ or Maternal Health Services/	57772	25	(MH "Postnatal Care+") OR (MH "Postnatal Period+") OR (MH "Postpartum (Omaha)") OR (MH "Postpartum Care (Saba CCC)")	18,932
26	1 or 2 or 3 or 4 or 21	1096963	26	1 or 2 or 3 or 4 or 21	1002523	26	(MH "Perinatal Care") OR (MH "Perinatal Risk (Saba CCC)+") OR (MH "Perinatal Care (Saba CCC)+")	4,504
27	5 or 6 or 7 or 8 or 9 or 10 or 11 or 22	3040093	27	5 or 6 or 7 or 8 or 9 or 10 or 11 or 22	1874856	27	(MH "Maternal Health Services") AND (MH "Emergency Medical Services")	76
28	15 or 16 or 23	1220459	28	15 or 16 or 23	827429	28	S1 OR S2 or S3 or S4 OR S21 or S22	283,819
29	7 or 12 or 13 or 14 or 24	843558	29	12 or 13 or 14 or 24	566764	29	S5 OR S6 OR S7 or S8 OR S9 OR	500,843

							S10 OR S11 OR S23	
30	19 or 20 or 25	157934	30	19 or 20 or 25	58102	30	S15 OR S16 OR S24	301,973
31	26 or 27 or 28 or 29 or 30	4526140	31	26 or 27 or 28 or 29 or 30	3006880	31	S7 OR S12 OR S13 OR S14 OR S25	210,882
32	18 and 31	158	32	18 and 31	104	32	S19 OR S20 OR S27	468)
						33	S28 OR S29 OR S30 OR 31 OR 32	828,815
						34	S18 AND 33	50

Supplementary Figure 1. Mapping tool for narrative review of signal functions

Answer the following questions in sequence	**Yes**		**No**
Q1. Is the title/abstract about facility-based care for reproductive, maternal, newborn, child health (RMNCH)	Assess by Q2.		Exclude.
If yes, then:			
Q2. Is the title/abstract applying or discussing the concept of signal functions to measure, monitor facility-based care OR providing a critique or comment on signal functions for measurement of facility-based care?	If yes or unclear: Include for assessment of full text and proceed to Q3.		Exclude.
Q3. Does the article provide insights to the review objectives (i.e. meets some of the following criteria): • Describes a novel approach or experience in the use or application of signal functions • Describes strengths or weaknesses of the signal function approach or critiques the signal function approach • Provides recommendations on the application or use of signal functions OR • Is a seminal piece referenced and/or recommended by experts in the field	If yes, include for final meta-narrative review.	If unsure, mark as yellow for further discussion before categorising as green or grey.	If no, include for full text review.